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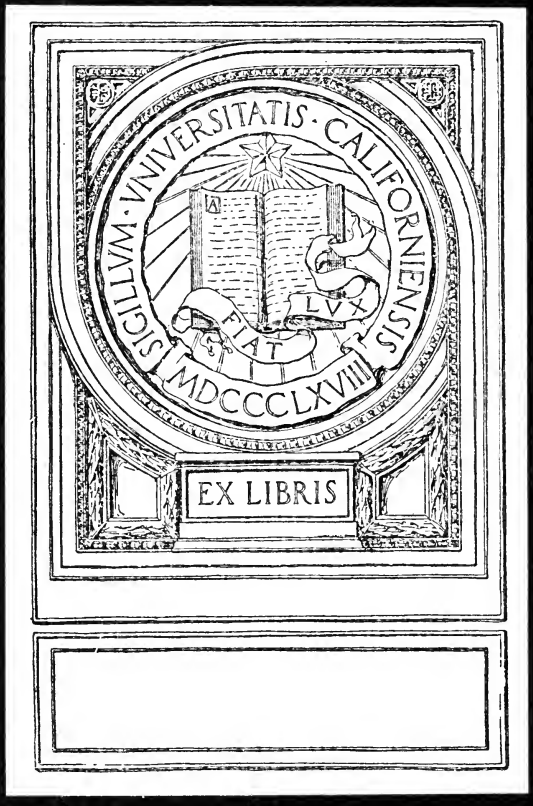
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Study of the elements of cost of canal transport.

(being N° 3 of the series of Questions submitted for consideration.)

REPORT

BY

G. RENAUD

Inspecteur général des Ponts et Chaussées en retraite, à Paris.

Executive Committee — Secretary General

38, Rue de Louvain, 38

Brussels

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UNIV OF
CALIFORNIA

Study of the elements of cost of canal transport.

§ 1. Subject of the investigation.

The following study has been drawn up with a view to assessing the reduction obtainable in the cost of transport of goods on the proposed North-Eastern canal, on condition that lighters or barges of 500 to 600 tons are substituted for vessels of 280 tons, as was contemplated in the original scheme. (1)

The data regarding the mileage and organisation of the traffic, which have been used in the calculations, relate to this canal, which is specially designed for the carriage of heavy freights of minerals and fuel; but the results of the deductions apply equally to any canal designed for heavy traffic and suitably fitted as regards the haulage of barges, and having proper means of handling the freight at the port of delivery.

In order to give a definite basis to the discussion we have assumed;

(1) That the main bulk of traffic, consisting of minerals and fuel, would be carried by a fleet, belonging either to companies

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(1) The North-Eastern canal is designed to link up the mining and manufacturing districts of Meurthe-and-Moselle, the Meuse, the Sambre and the Escaut, and connect them with the coal mines and foundries of the North and the Pas-de-Calais, as well as with the port of Dunkirk and the great artery of navigation formed by the Meuse.

It will start from the Escaut, in the reach of Denain, will cross the canal linking up the Sambre to the Oise, will cross the Meuse at Mezieres, and will finish in the Meurthe-and-Moselle, where two ports, constructed at Lenguyon and Pierrepont, will link it up with the manufacturing and mining districts of Longwy and Briey.

Technical considerations in regard to the construction have caused us to limit this investigation to vessels of 600 tons.

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or to syndicates of manufacturers, and running on a regular schedule.

(2) That the canal system would be electrified throughout its entire length, and the regular working would be assured by means of fixed time-tables.

(3) That all ports would be properly fitted with the necessary plant for the prompt carrying out of the work of loading and unloading.

§ 2. Details of the expenses of a barge.

The expenses of a barge can be divided up into annual general expenditure, which should be portioned out pro rata in accordance with the number of journeys completed, and special expenditure chargeable to each separate journey. The general expenditure includes the redemption of the original purchase price, the up keep and major repairs of the hull, the wages of the crew, the cost of insurance, the purchase, upkeep and renewing of the rigging, the cost of the concession or expenses of management.

The portion of these expenses, appertaining to each ton carried, depends moreover on the number of journeys made annually and on the ratio between the freight carried on the return journey and the outward journey.

We have considered the variations in these freights as regards a barge of the type of a Flemish peniche, capable of navigating at various drafts, and also as regards special barges or lighters, and also as regards specially designed barges of various tonnage. We have assumed that the journey in one direction would be made under full load, whilst on the return journeys the amount of freight carried would vary according to the quantity available. The calculations, drawn up for purposes of comparison, only deal with the expenses pertaining to the carriage of goods; they do not include the taxation which might be levied either on the barge or the goods.

The length of the journey has been taken as being 321 kilometres (199,463 miles English), that being the length of the proposed canal from Lens to Lenguyon. We have taken the outward journey

as being at full load and the return journey as, either empty throughout, or empty every other trip, or empty every fourth trip, or as fully loaded.

Annual general expenditure.

Peniches. — The peniche in ordinary use on the Northern and Eastern canals is of the type of a Flemish peniche, a craft of rectangular shape, which may be normally described as follows :

Length	37.50 metres (123 feet)
Width	5.00 metres (16 ft. 5 in)
Coefficient of displacement	98%
Tonnage at a draft of about 1.80 m. (5 ft. 10 in.)	280 tons
Tonnage at a draft of about 2.20 m. (7 ft. 4 in.)	350 tons

The annual general expenditure may be set out as follows (1).

The cost of a peniche averages about 11,000 francs (about £440) and that of the spars and rigging 1,500 francs (about £60).

The life of such a vessel is about 30 years. During this period the hull generally undergoes two main overhauls, and two minor overhauls, as follows:

At the end of eight years, a general inspection including the overhaul of the bottom, which entails an expense of from 400 to 600 francs (about £16 to £24), and may be taken as averaging 500 francs (£20).

After fifteen years, a complete overhaul, which includes more especially the repairing of the bottom boards, the repair of the rabbets and the sheave-holes, and the strengthning of the bows, etc., amounting in all to about 1,500 to 2,500 francs (about £60 to £100), and which may be taken as averaging 2,000 francs (£80).

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(1) We have found the majority of the data which follow, in the very complete study made by Mr. Grüner (The navigable canals of the North of France leading to Paris) and in the work by Mr. Charles Lavaud (Matériel de la batellerie et essais de résistance à la traction) which contains the results of most carefully carried out tests, and which they kindly placed at our disposal. These works have greatly aided our researches.

After twenty years, another main overhaul which includes more especially the repair of the bottom of the hull and a considerable portion of the timbers, costing from 2,500 to 3,500 francs (about £100 to £140), and which may be said to average about 3,000 francs (about £120).

Finally, after twenty six years, a final inspection similar to the first and costing on an average about 500 francs (£20).

These various expenses, deducting the value of the peniche and its spars and rigging when sold for breaking up, represent, (1) at the time of purchase, a sum of about . . . . . 2,300 francs (about £ 92)

If we add to this amount the cost of purchase . . . . . 12,500 francs (about £500)

We find we require a capital of . . . . . 14,800 francs (about £592)

On which the interest and sinking fund reckoned at the rate of 5% amount to an annual charge of about. . . . . 960 francs (about £38)

The cost of maintenance which must be added to this annual charge, includes the following expenses :

(1) Tar, paint, wood, etc., for the maintenance of the hull . . . . . 75 francs (about £3)

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(1) According to the tables drawn up by Mr. Grüner, at the rate of 5%.

500 francs (£ 20) payable in 8 years	500 × 0.677 =	399
2,000 francs (£ 80) payable in 15 years	2,000 × 0.481 =	962
3,000 francs (£120) payable in 21 years	3,000 × 0.359 =	1,077
500 francs (£ 20) payable in 26 years	500 × 0.281 =	141
	Total	2,519
Deduct from the above:		
1,500 francs (£ 60) payable in 30 years	1,000 × 0.231 =	213
	Remaining total:	2,288

(2) Purchase of rope . . . 115 francs (about £4.10.0,

(3) Renewal of masts, lamps, tools, etc. . . . . 80 francs (about £3)

(4) Labour.

The master of the peniche usually carries out the running repairs himself. We may presume that the assistance of outside labour will be necessary in the case of continuous service, where the halts of the barges will be shorter than are usually the custom in the barge trade. We may therefore allow under this item . . . . . 100 francs (about £4)

The total expenditure relating to the hull and the rigging therefore amounts to . . . . 1,330 francs (about £53)

The crew is composed of the master and his wife, whose wages come out at 5 francs(4 shillings) per diem. This will amount to an annual expenditure of 1,825 francs (£73), to which must be added a further 100 francs (£4) for fuel and light, making a total of 1,915 francs (£77).

Insurance will amount to 175 francs (£7).

If we set down the share of each peniche in the general expenses of management as 400 francs (£16), we arrive at a total of 3,830 francs (about £153), as the annual general expense of upkeep, made up as follows :

Expenses with regard to the hull and rigging	1,330 francs	(about £53)
Crew	1,925 francs	(about £77)
Insurance	175 francs	(about £7)
Expenses of management	400 francs	(about £16)
Total about. . .	3,830 francs	(about £153)

Special barges. — The type of barge which we have taken into consideration is that of a barge with sharp bows, to facilitate

traction. The coefficient of displacement we may take as being 90 %.

The calculation has been drawn up for barges capable of carrying freights of 400, 500 and 600 tons respectively.

The calculation of annual general expenditure for each of these types of barge has been drawn up, as follows·

The societies or syndicates, owners of consignments, may consider it advantageous to build iron instead of wood barges; but this question, which cannot be dealt with here, is of merely secondary importance from the point of view of the results of these calculations. They have been arrived at, on the supposition that the barges are built of timber, like the peniches, having the same life and requiring similar repairs (1).

From the figures given above, the hull of a peniche comes out at 31 fr. 40 (about 25 shillings) per ton of load, when the barge is fully loaded. The construction of barges with pointed or schooner ends, allows of certain demands which entrain an appreciable increase of expense, and the price of such hulls may be estimated at an average of 36 francs (about 28 shillings) per ton of load (2); the cost of maintenance of the hull, and those of the rigging and tools will increase with the tonnage, in a varying degree.

The number of hands required for the crew of boats of greater dimensions than a peniche has given rise to controversy. It has been claimed that the master should be allowed a bargeman; but on the other hand some builders claim that a well fitted barge can be managed by a single man. We have come to the conclusion that this was more a question of greater or less security against accidents, and that a company, desirous of insuring the reliability of a regular traffic, would place a bargeman on board loaded barges, and that he would be transferred to another barge in the

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(1) We may reckon that an iron barge costs half as much again as a wooden barge of the same tonnage; but it lasts much longer and does not require the same heavy repairs.

(2) From the price paid by the Navigation Company.

event of the barge on which he primarily was stationed, returning empty, as is the usual custom in the barge trade.

It is necessary to include the wages of the master in the annual expenditure, and the wages of the extra hand in the cost per trip.

The cost of insurance and the expenses of management have been considered as proportional to the tonnage.

The following table gives the total of the general annual expenditure for each of the three types of barge under consideration:

	TONNAGE OF BARGES		
	400 tons	500 tons	600 tons
	Francs	Francs	Francs
a. *Capital value on day of purchase :*			
Hull	15,000	18,000	21,500
Majors repairs (1)	2,700	3,400	4,000
Rigging	1,500	1,600	1,800
	19,200	25,000	27,300
£	768	1,000	1,092
b. *Annual general expenditure :*			
1° Interest and sinking fund on the capital at 30 years (2) . . .	1,248	1,508	1,775
2° Tar, paint, timber, etc., for the maintenance of the hull . . .	100	125	150
3° Purchase of rope	135	155	175
4° Renewals of masts and yards, lamps, tools, etc.)	95	110	125
5° Labour and maintenance . .	130	150	200
6° Crew	1,925	1,925	1,925
7° Insurance	230	290	350
8° Cost of management	550	700	800
TOTALS . . .	4,413	4,963	5,500
About £	176.10.0	198.10.0	220

(1) After deduction of the « breaking up » value.
(2) At. 5 %.

Number of annual trips. — The time taken for a return journey may be estimated als follows:

The length of the voyage is 321 kilometres (199.463 miles English). If we assume, according to the usual custom, that the passage through a lock takes as long as the journey over a distance of 1 kilometre (.621 miles English), and that the number of locks amounts to 36, the total effective length of the journey will be equivalent to 357 kilometres (221.835 miles English); the daily travel may amount to 15 hours travelling, in accordance with the previsions of the Northern Canal; but it is adviseable not to reckon on a longer effective rate of travel than 12 hours, in order to allow for loss of time and slowing down. The speed of the barge being limited to 3 kilometres (1.864 miles English) per hour, the effective daily run will be 36 kilometres (22.368 miles English); the duration of the journey will thus amount to 10 days for the single trip or 20 days for the trip there and back.

The mechanical appliances on the quays should usually allow of the loading or unloading to be completed in one or two days, except in cases where some mishap at the arrival may accidentally cause a delay. The barge which has to return empty should start immediately the unloading is completed. Those which have to take in a fresh cargo will often have to proceed to some other point in the district to pick it up. Allowing an average of 12 days, for the business of loading and unloading, and to include any possible loss of time, we arrive at a total of 32 days as the average duration of a return journey.

The number of days utiliseable in a year may be estimated at 320, allowing for stoppage of work and frost. The number of return journeys would thus amount to 10 per annum. But these estimates may be upset by various accidents in the working, by delays in delivery, by repairs rendered necessary. The calculations have been drawn up to meet either case, where the number of annual return journeys are either 8 or 10.

The following table shows the proportion of the total general expenditure as shewn above, which is chargeable to a return journey in the case of each of the types of barges under consideration.

	NUMBER OF ANNUAL JOURNEYS	
	8	10
Peniches.	479	383
400 tons barge	552	441
500 »	620	496
600 »	687	550

Cost per journey.

The costs per journey include the cost of traction and the incidental expenses.

Cost of traction. — The estimate of the cost of traction has been drawn up on the following hypothesis:

that the traction rights shall be a monopoly;

that the traction shall be electrical, and that the necessary current shall be obtained by means of the available gas from the existing coke ovens and blast furnaces in the neighbourhood;

that the rail tractors installed by the Company of Electric Haulage, along the banks of the Aire, Deule, and Sensee canals, between Bethune and the Escaut, over a distance of 70 kilometres (43.497 miles English), should be made use of;

that the speed of the barges should be 3 kilometres (1.864 miles English) per hour.

The calculations have been drawn up by applying the following scale of prices:

(A.) — FOR LOADED VESSELS

Cost of traction per ton-kilometre:

1° *Peniches:*

For the first 300 tons	0.003	francs
Per ton additional	0.0021	»

2° *Barges with sharp bows:*

For the first 300 tons	0.0021	francs
Per ton additional	0.0015	»

(B.) — FOR EMPTY VESSELS

Cost of traction per kilometre:

Peniches	0.36
400 ton barges	0.41
500 ton barges	0.45
600 ton barges	0.50

The use of electrical power and the establishment of a monopoly in traction, fulfil the requirements of main canals designed for heavy freights. We shall not waste time in proving this.

We have come to the conclusion that the system of rail tractors as used by the Northern Electric Company gives us in this case the most accurate basis of calculation, as it has been thoroughly tested in practice. We must however allow that it may be possible in future to suggest other methods whch may prove more advantageous (1).

The management have decided that the speed limit for barges on the length of canal between Bethune and the Escaut, and on the Northern Canal, shall not exceed 3 kilometres (1.864 miles English) per hour. A speed of 4 kilometres (2.486 miles Engish) would double the tractive resistance, as this latter increases as the 2.25 power of the speed, the cross-sectional area of the canal remaining constant. The economy obtained in the time saved on the haulage would not compensate for the greatly increased cost of traction, unless the cross-sectional area of the canal was increased at great expense.

Besides, we have been informed that the bargemen would object to a higher speed than 3 kilometres (1.864 miles English) on the

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(1) A recent paper, on the subject of the system used by the General Electrical Company of Nancy, which is in actual use by the Fougerolle Company in the underground workings at Mauvages, has further proved the correctness of the present report as regards the amount that may be saved by the use of barges of heavy tonnage

canal. We have consequently estimated the expenses of traction on the basis of the speed of 3 kilometres per hour.

Scale of charges. — The arrangement of the scale of charges and the amounts shown therein have been determined by the following considerations :

The scale of charges in operation between Bethune and the Escaut is made up of two items. The first part takes into consideration the permissible loading, which in the case of a peniche drawing 1.80 metres (about 5 ft. 10 in.) as laid down in the regulations, is about 300 tons; the second portion takes into consideration the weight of the freight itself. The charges made by the Company of Electrical Haulage are as follows, per ton kilometre, for the up journey and the down respectively.

Possible tonnage	0.0015 fr.	0.00125 fr.
Per ton of freight	0.0020 fr.	0.00175 fr.

The average tonnage in 1910 amounted to 3.700.000 tons. The tonnage "up" is distinctly more than the tonnage "down". The Company does not possess a monopoly and 4/10ths of the barges are towed by horses.

The average tonnage on the North-Eastern canal is likely to exceed the above figure and the majority of the tonnage will be carried on the "down" journey. The whole of the barges will make use of electric traction owing to the institution of a monopoly. The reaches are longer between Bethune and the Escaut than they will be on the North-Eastern canal; but this advantage is counteracted by the fact the horse-towed barges impede the passage of those which are hauled by electric tractors, on the stretch between Bethune and the Escaut.

The general operating expenses, of sinking fund, and maintenance, which constitute the major portion of the expenses of an electric installation, will be less burdensome per ton of freight carried on the North Eastern canal, than on the canal system worked by the Company of Electrical Haulage.

According to the schedule of charges mentioned above, a peniche fully loaded would pay, per kilometre, 1.05 fr. (about 10 pence) on the way up, and 0.90 fr. (about 8 1/2 pence) on the way down.

We consider we are making sufficient allowance in assuming that the same barge, passing over the North-Eastern canal, would only have to meet a charge of 0.90 fr. (about 8 1/2 pence) per kilometre, that is 0.003 fr. per ton-kilometre.

But the cost-price of traction of a barge is the sum of a constant and a variable, proportional to the weight hauled.

The haulage companies of the Lower-Seine, reducing this to a simple formula, charge in full for the first 300 tons of freight carried by a barge, and half-price for as many tons as there may be in excess of the 300. This method is perfectly logical, and an examination of the figures shows that the variation in the prices is in a fair ratio to the extra work entailed in hauling the barges, in the limits within which their tonnage varies on the Lower Seine.

Paragraph 1 of the scale of charges applicable to peniches, has been based on a formula similar to that in use on the Lower Seine. in the case of peniches drawing more than 1.80 metres (5 ft. 10 in.); but we have thought it adviseable, after going fully into the matter, to only allow of a reduction of 30 %, as the profits to be expected from the expenses of traction, with regard to the extra freight charge, are less on a canal than on the Seine, taking into consideration the general conditions of navigation in each case.

On the other hand, the power necessary to haul a barge, whose ends are suitable shaped, along a canal, is but little more than half what is required for a peniche of the same tonnage, so that the labour is approximately the same to haul one peniche or two barges, each of the latter being of the same tonnage as the peniche.

Taking into account the presence of a constant in the formula, to express the work entailed in traction, we come to the conclusion, after careful consideration, that the reduction in price for barges should be in the proportion of 30 %, as shown in paragraph 2.

The charges shown in paragraph B, as regards the haulage of empty barges, etc., were drawn up after similar consideration.

Calculation of the cost price of traction. Before applying the scale of charges decided upon by these general estimates, it became necessary to verify how far they would agree with the net

expenses of haulage, according to the different types of vessel under consideration.

The estimating of these expenses has been the object of a special study, carried out by our collaborateur Mr. Brot, Ingenieur des Arts et Manufactures, from the following data (1).

The system of traction is still that of the (rail) tractor, the effective speed remains 3 kilometres (1.864 miles English) per hour. The necessary energy to haul each vessel has been calculated from the data obtained in the course of his experience by Inspector General de Mas, and from tests made with the tractors of the Haulage Company, taking into account the various cross-sectional areas of the canal and of the vessel, and the shape of the latter. The electrical energy required is taken as being obtained by the use of the gas obtainable from the various manufacturing works, and supplied by them to the Haulage Company at a price of 0.06 fr. per kilowatt-hour.

The calculations had to take into account three items, to wit:

1. The general expenses corresponding to the sinking fund and the upkeep of the fixed plant, and the cost of management;

2. The standing charges common to the whole fleet of vessels hauled, corresponding to the sinking fund, upkeep and driving of the tractors;

3. The cost of the electrical energy consumed effectively by each vessel.

The canal when fully open, will allow the simultaneous passage through of peniches and of barges, which will make use of the means of traction available. It was necessary to lay down a rule to separate the two first items of expenditure among the various types of vessels, so as to decide on the expense that should be set down against each type. We have taken this expenditure as being subdivided as follows:

The sinking fund and upkeep of the fixed plant and the costs of management have been assessed equally per ton of freight carried.

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(1) Mr. Imbeaux, Engineer in chief, has been kind enough to place at our disposal a report very carefully drawn up by his staff, in view of a similar installation. Mr. Brot has made use of the data contained therein.

Each vessel has been assigned a charge representing the hire value of the tractor over the distance hauled.

Each vessel has been further charged with a sum representing the value of the amount of electrical energy it consumes.

We considered that this method of subdivision of the expenditure was best adopted to the circumstances. It must be noted that it assesses the larger barges with a proportion of the expenses greater than that assessed by other methods (1).

Our comparative calculation has taken into account the double hypothesis:

1. Of a canal built solely with a view to the passage of peniches, loaded to a draft of 1.80 to 2.20 metres (5 ft. 10 in. to 7 ft. 4 in.) according to the moorings.

2. Of a canal built with a greater cross-sectional area and accessible to barges of 500 to 600 tons.

As a matter of fact the tonnage carried will be greater on a canal of the latter type than on that of the former type, the use of vessels of heavy tonnage having the effect of appreciably lowering the cost of freight and widening the radius of action of the canal. Thus the amount of total tonnage is a most important factor in the cost price per ton-kilometre. So as to obtain as accurate as possible a view of the facts of the case, while taking into account the present estimates concerning the traffic on the canal, we have calculated the actual cost price corresponding to a traffic of:

3,500,000 to 4,000,000 tons in the case of a canal with a restricted cross-sectional area.

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(1) The calculations have been also drawn up in two other ways; in one Mr. Brot has determined a price per kilowatt-hour, obtained by dividing the whole of the expenses of management, sinking fund, maintainance, working costs, and purchase of current, by the total number of kilowatt-hours consumed per annum, and he has assessed the cost of traction of each vessel from the number of kilowatt-hours supply it will consume.

In another method, Mr. Brot has taken the expenses of management, of the fixed working plant, and of the tractors, as being evenly portioned out to each ton of freight carried, each ton being further charged with the cost of the current consumed for its transport, according to the type of vessel in which it is carried.

and of 4,700,000 to 4,700,000 tons in the case of a canal with a large cross-sectional area.

The following tables, drawn up in view of the above conditions, show the ratios between the cost price as obtained by direct calculation and that obtainable from the schedule of costs we have made use of.

COST PER TON-KILOMETRE

Type and draft of vessel	COST		Standing charges in thousandths of a franc	Total working cost in thousandths of a franc	Charges adopted in thousandths of a franc	Ratio of the charges adopted to the total estimated working cost in thousandths of a franc
	of the use of the tractor in thousandths of a franc	of electrical energy in thousandths of a franc				
CANAL WITH A RESTRICTED CROSS-SECTIONAL AREA						
1° Annual traffic of 3,500,000 tons						
Peniches of 280 tons	0.704	0.772	1.071	2.547	3.000	1.18
» 300 »	0.572	0.755	1.071	2.398	2.871	1.20
2° Annual traffic of 4,000,000 tons						
Peniches of 280 tons	0.704	0.772	0.937	2.413	3.000	1.24
» 300 »	0.572	0.755	0.937	2.264	2.871	1.27
CANAL WITH WIDE CROSS-SECTIONAL AREA						
1° Annual traffic of 4,200,000 tons						
Barge of 400 tons	0.500	0.312	0.893	1.705	1.950	1.14
» 500 »	0.400	0.283	0.893	1.576	1.860	1.18
» 600 »	0.332	0.265	0.893	1.490	1.800	1.21
2° Annual traffic of 4,700,000 tons						
Barge of 400 tons	0.500	0.312	0.798	1.610	1.950	1.21
» 500 »	0.400	0.283	0.798	1.481	1.860	1.26
» 600 »	0.332	0.265	0.798	1.395	1.800	1.29

SUMMARY

	Ratios between the charges adopted and the total estimated working cost.	
	In cases of minimum traffic.	In cases of maximum traffic.
Canal with restricted cross-sectional area . . .	3,500,000 t^s to 4,000,000 t^s	
Canal with wide cross-sectional area	4,200,000 t^s to 4,700,000 t^s	
Peniches of 280 tons.	1.18	1.24
» 350 »	1.20	1.27
Barges of 400 »	1.14	1.21
» 500 »	1.18	1.26
» 600 »	1.21	1.29

This summary shows:

that the working cost varies with the amount of the traffic;

that the ratio between the charges adopted according to the scale and the total estimated working cost are approximately the same both for peniches or barges carrying varying amounts of freight, in the cases of the minimum traffic taken into consideration;

that the same applies in cases of maximum traffic;

that the prices charged allow a margin over and above the estimated working cost.

We may conclude that paragraph A (loaded vessels) approximately satisfies the conditions of the service, within the limits of the amount of traffic we have considered.

These limits allow a margin of 500,000 tons in the case of both types of canal under consideration. This margin may be exceeded in the future; which would bring about a lessening of the working cost.

The results of this survey appear to guarantee us against unforeseen expenditure, and to be capable of being used as a basis of comparison between the various types of vessels.

Incidental expenditure. — The incidental expenditure includes, for all types of vessels, the trimming of the cargo, the gratuities to the staff of the harbors and to the traction departement, the

expenses of lighting, etc.... It comes out, in the case of peniches, at about 15 francs (about 12 shillings) per journey empty, and to 32 to 40 francs (about 25 to 32 shillings) per journey loaded with from 280 to 300 tons. It will increase to a varying amount in the case of barges of greater tonnage than peniches. In addition to to these primary expenses, barges will also have to bear the expense of the wages of an extra hand, who will be taken on board when the barge is carrying cargo, as has been previously agreed upon. The corresponding expenditure may be set down as 60 francs (about £2.8.0) per journey when loaded, being at the rate of 4 francs (about 3 shillings and 3 pence) per diem, for each of the ten days of the journey, in addition to the allowance for loss of time or expenses of return by land.

Total expenditure per journey. The total expenses per journey may therefore be thus set down, in the case of vessels proceeding under full load or when empty.

	TYPE AND TONNAGE OF VESSELS				
	Peniches		Barges		
	280 tons	350 tons	400 tons	500 tons	600 tons
Per journey loaded					
Cost of traction	Fr.	Fr.	Fr.	Fr.	Fr.
321 kilomètres at 0.84	270				
» 1.00		321			
» 0.78			251		
» 0.93				298	
» 1.06					347
Incidental expenditure	32	40	104	112	120
Totals per journey loaded	302	361	355	410	467
About. . £	12	14.8.0	14.4.0	16.8.0	18.13.0
Per journey empty					
321 kilometres at 0.36	116	116			
» 0.41			152		
» 0.45				144	
» 0.50					161
Incidental expenditure	15	15	17	19	21
Totals per journey empty	131	131	149	163	182
About. . £	5.5.0	5.5.0	5.19.0	6.10.0	17.6.0

§ 3. Cost of carriage of goods.

The two following tables, drawn up from the foregoing data, show the working cost per ton-kilometre, when carreed in peniches or barges, according to the type or tonnage of the vessels and the importance of the return freight.

PENICHES

Load and draft	Number of journeys per annum	Cost per journey: Outward loaded	Cost per journey: Inward	Proportion of annual cost	Totals	Corresponding tonnage	Cost: Per ton carried (francs)	Cost: Per ton-kilometre, 8 journeys per annum (thousandths of a franc)	Cost: Per ton-kilometre, 10 journeys per annum (thousandths of a franc)
					Returning empty				
280 ts	8	302	131	478	911	280	3.25	10.12	
1m80)	10	302	131	383	816	280	2.91		9.06
350 ts	8	361	131	478	970	350	2.77	8.62	
2m20)	10	361	131	383	875	350	2.50		7.78
					Returning empty every other journey				
280 ts	8	302	217(1)	478	997	420(2)	2.37	7.38	
1m80)	10	302	217	383	902	420	2.14		6.66
350 ts	8	361	246(3)	478	1085	525(4)	2.06	6.41	
2m20)	10	361	246	383	990	525	1.88		5.85
					Returning empty every fourth journey				
280 ts	8	302	259(5)	478	1039	490(6)	2.12	6.60	
1m80)	10	302	259	383	944	490	1.92		5.98
350 ts	8	361	303(7)	478	1142	612(8)	1.86	5.79	
2m20)	10	361	303	383	1047	612	1.71		5.32
					Returning loaded				
280 ts	8	302	302	478	1082	560	1.93	6.01	
1m80)	10	302	302	383	987	560	1.76		5.48
350 ts	8	361	361	478	1200	700	1.71	5.32	
2m20)	10	361	361	383	1105	700	1.57		4.89

(1) $\frac{302+131}{2} = 216{,}5$ (2) $\frac{361+131}{2} = 246$ (3) $\frac{3\times302+131}{4} = 259{,}25$ (4) $\frac{3\times361+131}{4} = 303$

(5) $\frac{3\times280}{2} = 420$ (6) $\frac{3\times350}{2} = 525$ (7) $\frac{7\times280}{4} = 480$ (8) $\frac{7\times350}{4} = 612$

BARGES

Load and draft	Number of journeys per annum	Cost per journey		Proportion of annual cost	Totals	Corresponding tonnage	Cost		
		Outward loaded	Inward				Per ton carried francs	Per ton-kilometre 8 journeys per annum Thousandths of a francs	Per ton-kilometre 10 journeys per annum Thousandths of a francs
Returning empty.									
400 tons	8	355	149	552	1056	400	2.64	8.22	
	10	355	149	441	945	400	2.36		7.35
500 »	8	410	163	620	1193	500	2.38	7.44	
	10	410	163	496	1069	500	2.14		6.66
600 »	8	467	182	687	1336	600	2.22	6.91	
	10	467	182	550	1199	600	1.99		6.19
Returning empty every other journey.									
400 »	8	355	252(1)	552	1159	600	1.93	6.01	
	10	355	252	441	1048	600	1.74		5.42
500 »	8	410	286(2)	620	1316	750	1.75	5.51	
	10	410	286	496	1192	750	1.65		4.95
600 »	8	467	325(3)	687	1479	900	1.64	5.10	
	10	467	325	550	1342	900	1.49		4.64
Returning empty every fourth journey.									
400 »	8	355	304(4)	552	1211	700	1.73	5.38	
	10	355	304	441	1100	700	1.57		4.89
500 »	8	410	349(5)	620	1379	875	1.57	4.89	
	10	410	349	496	1255	875	1.43		4.45
600 »	8	467	396(6)	687	1550	1050	1.47	4.54	
	10	467	396	550	1413	1050	1.34		4.17
Returning loaded.									
400 »	8	355	355	552	1262	800	1.57	4.89	
	10	355	355	441	1151	800	1.44		4.45
500 »	8	410	410	620	1440	1000	1.44	4.45	
	10	410	410	496	1316	1000	1.32		4.10
600 »	8	467	467	687	1621	1200	1.33	4.20	
	10	467	467	550	1484	1200	1.23		3.83

(1) $\frac{355+149}{2} = 252$

(2) $\frac{410+163}{2} = 286$

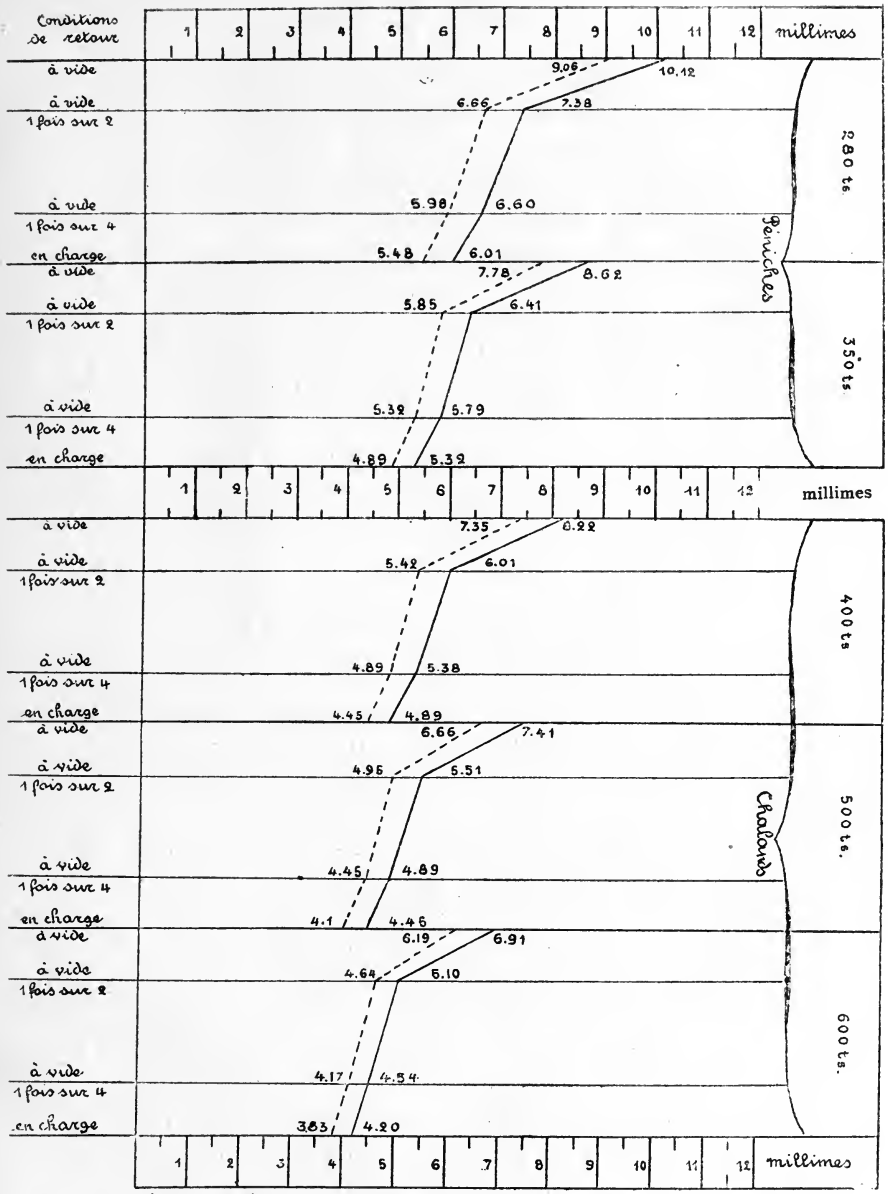
(3) $\frac{467+182}{2} = 324.5$

(4) $\frac{3\times355+149}{4} = 303.5$

(5) $\frac{3\times410+163}{4} = 348.25$

(6) $\frac{3\times467+182}{4} = 395.7$

The results of these calculations are reproduced in the following graphs, which show the variations of cost price of carriage per ton-kilometre, according as the carriage is, by peniches or by barges of various types, and according to the greater or less amount of freight carried on the return journey.



Les traits pleins correspondent au cas de 8 voyages annuels et les traits ponctués au cas de 10 voyages.

Conditions de retour = conditions of return journey. | *à vide* = empty.
1 fois sur 2 = every other journey. | *Peniches* = Peniches.
1 fois sur 4 = every fourth journey. | *Chalands* = Barges.
en charge = loaded. | *Millimes* = Thousandths of a franc.

Les traits pleins correspondent au cas de 8 voyages annuels et les traits ponctués au cas de 10 voyages =

The heavy lines refer to the cases of 8 journeys per annum and the dotted lines to the cases of 10 journeys per annum.

The hypothesis applied with a view to simplification, and which consists in reckoning that each journey will take the same time, however many times the vessel may have to return empty, has the effect of exagerating the differences in price produced by the variation in the proportion of the amount of freight carried on the return journey; but it does not alter the general character of the graph.

An examination of the curves shows clearly;

on the one hand, the reductions in price which are obtainable from freight carried on the return journey and the continuity of the traffic;

on the other hand, those which are obtainable from an increase of tonnage and incidentally from the improvement in the shape of the vessel.

§ 4. Estimate of the freight rate.

The preceeding calculations allow us to establish a comparison between the different types of vessels considered from the point of view of the expense which their use entails on the ship-owner. But it is equally important to discuss what may be the real rate of freight.

As a matter of fact the total rate for transport paid on goods making use of the canal is regulated by the law of supply and demand; the goods rates of the railways step in to keep these below a certain fixed limit, which varies with the class of goods. Consequently the maximum amount of the rate which may be laid on each class of goods on a toll-canal — as is the case on the North Eastern canal — rises or falls according as the profit is sufficient to justify the existence of the barge industry. An increase of the size of the vessels would thus permit an increase of revenues, and by increasing the profit on the capital would establish a margin which would admit of a reduction of tariffs to create increased traffic.

But the question of the freight rate on a navigable way and with given working materials, is not a matter which may be definitely solved in the Engineer's study. The current prices, which are determined by the supply and demand, are affected by the scarcity or abundance of the materials, the magnitude of the orders obtained,

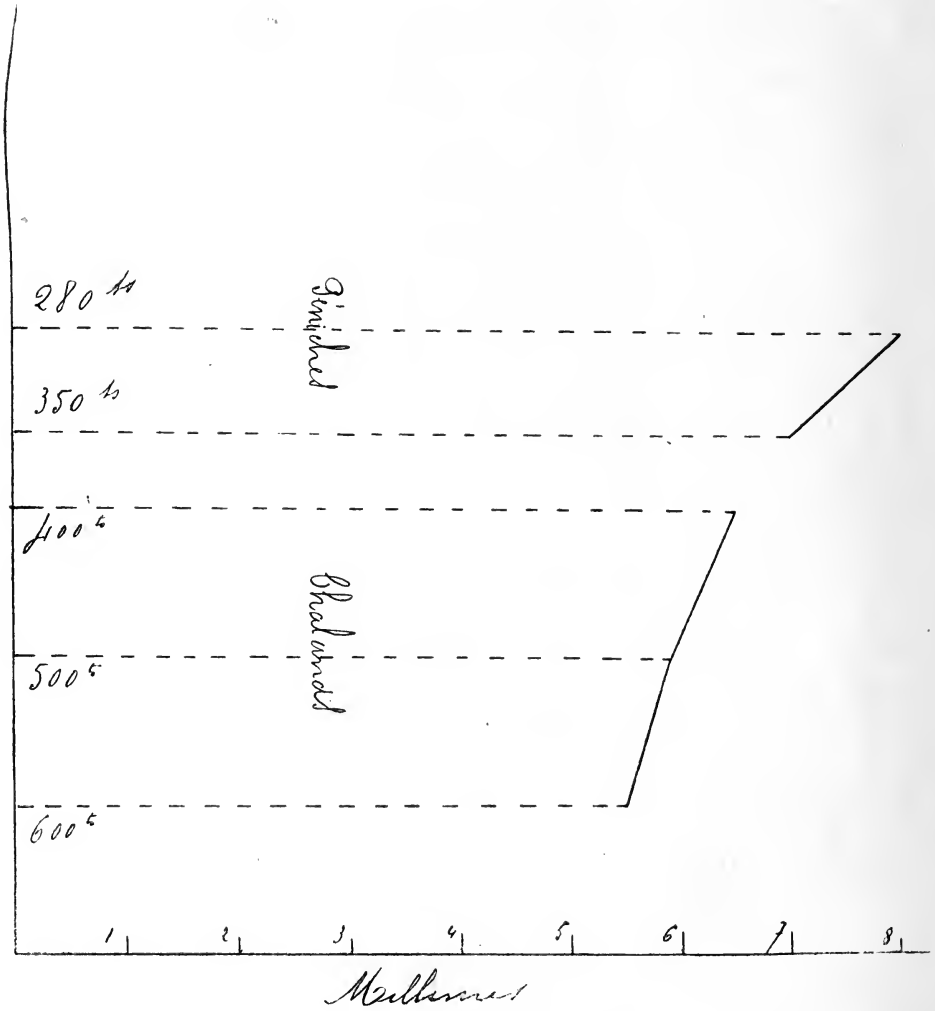
the conditions of working of the means of transport, the facilities for loading and unloading on the quays and by numerous outside contingencies.

It appeared to us possible to fix on reasonable previsions, as regards the normal value of rates on a canal such as the North Eastern, by starting from the cost price corresponding to average conditions of active traffic and return freights, and by increasing them by 20 % to allow for unexpected contingencies and profits. We have moreover considered, as average conditions, those which correspond to ten journeys per annum, with a return journey traffic equal to half of the outward traffic, or those corresponding to eight journeys per annum, with a return journey traffic equal to three-quarters of the ontward traffic, the length of journey remaining 320 kilometres (about 199 miles English).

The rates given have been deduced from the following figures, per ton kilometre.

TYPE AND TONNAGE OF THE VESSEL	Working cost in thousanths of a franc	Rate of freight in thousanths of a franc
Peniches 280 tons	6.63	8.0
» 350 »	5.82	7.0
Barges 400 »	5.40	6.5
» 500 »	4.92	5.9
» 600 »	4.59	5.5

These results are shown in the following graph.



Peniches = *Peniches.*
Chalands = *Barges.*
Millimes = *Thousandths of a franc.*

The prices calculated apply, as has been shown at the beginning of this report, to vessels forming part of a commercial fleet specially organised with a view to carrying on a regular service of

transport on the canal, for heavy merchandise supplied by a definitely established manuafacturing connection (1).

Peniches, worked singly on their masters' account and acting as carriers for any chance client, would not be burdened with the general expenses which fall on a commercial undertaking; but they would incur a considerable amount of extra expense owing to the loss of time incurred in waiting for freight. We may reckon that they would be capable ,on a well fitted canal, of carrying cargo at the rate of 10 thousandths per ton-kilometre, in accordance with the views of the general Committee of the Ponts et Chaussées, as regards vessels drawing the regulation 1 on. 80 (5 ft. 10 in.) on the majority of French canals.

Summary.

The present paper, drawn up on the subject of water transport by vessels having a tonnage of from 280 to 300 tons, and on the supposition that the canal has been constructed to cope with heavy commercial freight, shows the reduction which the barge industry can realise in its working expenses;

1. by means of increasing the tonnage of the boats, combined with the adoption of more pointed bows to facilitate towing;

2. by means of a regular system of traction and the installation of a properly designed plant at locks and ports along the canal, which will allow the number of journeys to be increased;

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(1) The prices in the schedule have served as a basis for the commercial study of the working of the North-Eastern canal, after having been slightly raised as a matter of precaution. So as to check the practical value of the figures thus obtained, we have made them come out as closely as possible to the freight rates in force in the barge industry, more especially those applying to the transport of fuel and minerals, between Nancy and the North, and Belgium. With this view, we have modified these latter prices, on the one hand to take into account the defective working system of obtaining freights and the absence of any regular organisation on the said canals, as is noted in the aforementioned work by Mr. Grüner, on the other hand owing to the expense of haulage by horse-traction. This has proved that the rates decided upon leave a certain margin, even if the superior capacity of barges over peniches is only slightly taken into account.

3. when the return traffic is in sufficient proportion to the outward traffic.

Nevertheless, the conclusions arrived at in this paper are only applicable to the consideration of a scheme for a navigable waterway, on three conditions, which are as follows.

Barges of heavy tonnage must only be made use of, so long as the freight, for which they are designed, is in sufficient quantities, for the tonnage of each shipment to take up the full capacity of the vessel, and on condition that the frequency of the shipments insures a sufficient number of journeys per annum. The use of smaller craft appears adviseable if the trade is of smaller amount.

The use of electric traction, on which our calculations are based, is costly and therefore demands a considerable sinking fund; the service can only be carried on at the prices quoted on condition that the traffic is considerable. Otherwise we may be driven to have recourse to other methods.

The assumptions which may be drawn up as regards the probable freight rates must be checked, as much as possible, by comparison with the freight rates in force on existing lines, and corresponding to known cases in barge practice

Paris, 26 May 1913.

G. RENAUD,

Inspecteur général des Ponts et Chaussées, en retraite.

Trans: Capt L. A. Kingston, M. I. A. E.

NOTE. — The Peniche is a long and comparatively narrow barge, with bluff bows, in use on the canals of North-Eastern Europe.

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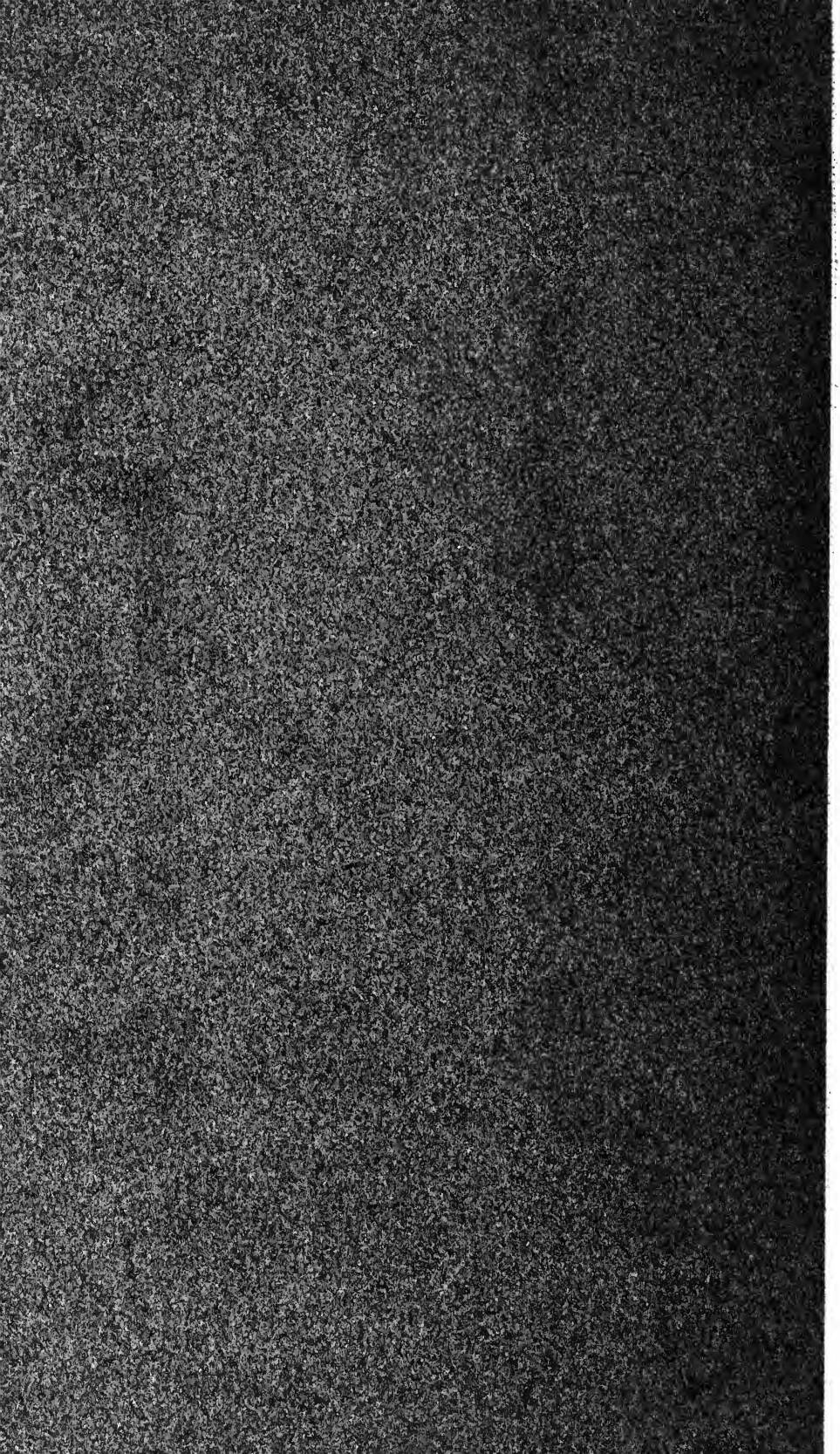
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